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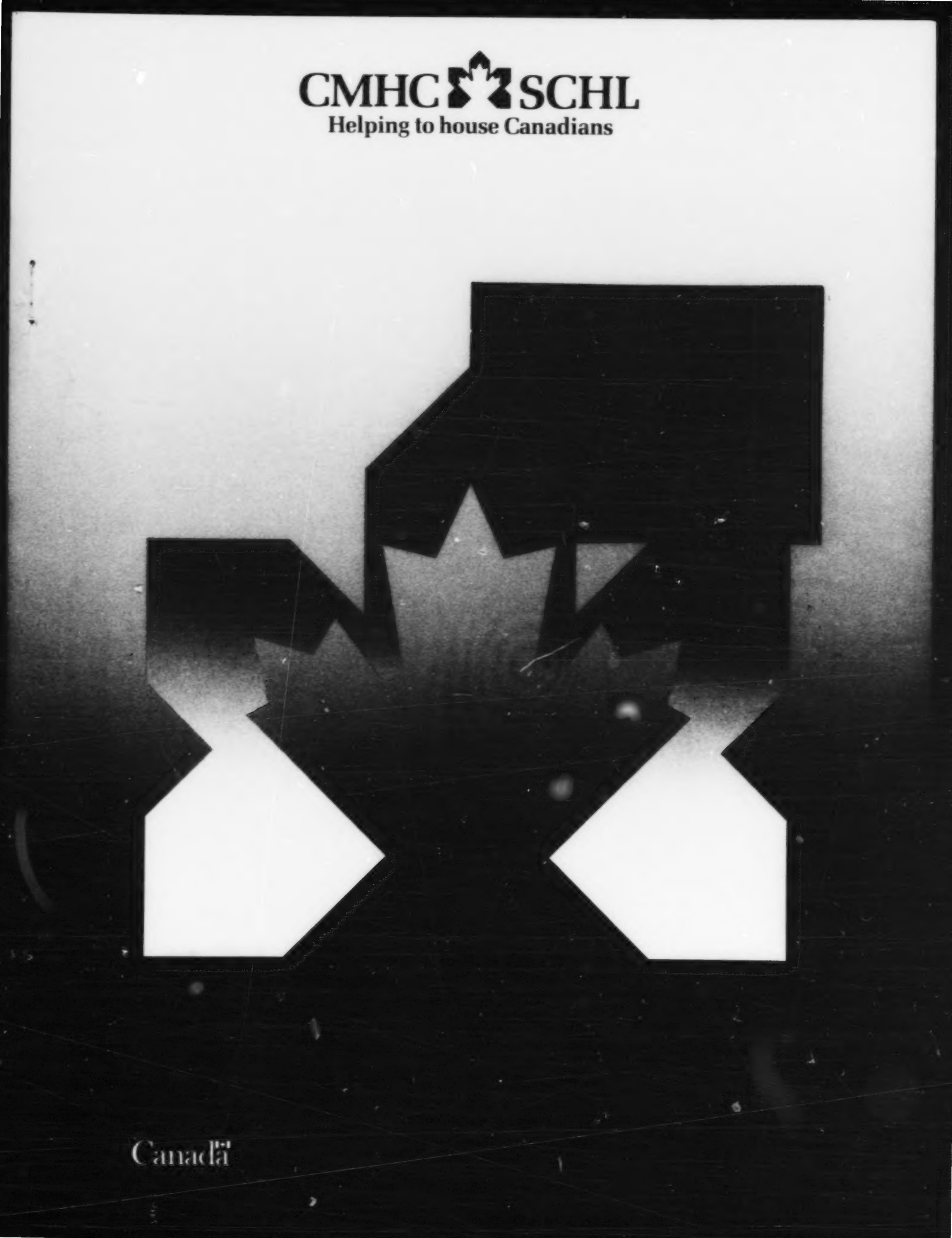

Canada

PORTABLE AUDIO-VISUAL TERMINAL FOR DISABLED PERSONS

Prepared for:

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ABSTRACT

This project focused on the evaluation of a "hands free" design concept for a home control system for persons with severe physical disabilities. This report covers the development and evaluation of a prototype system that consisted of two integral parts; a main control section which performed all the operational tasks, and a portable communications display terminal which provided voice access to the control section. The prototype was designed and assembled to determine the viability of using the unique communications terminal for voice control of home appliances, entertainment, communications and security devices.

The terminal and main control package were installed in the home of a quadriplegic person for testing. Both user response and technical performance characteristics were monitored during this period.

An evaluation of the test results highlighted any technical problems or limitations of the system's design and included recommendations for corrections and improvements to the functional capabilities of the system.

The concluding section highlights the potential of this system and also indicates some of the additional work necessary for the development of a marketable product.

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1.0 INTRODUCTION

The Neil Squire Foundation has been involved, for more than five years, with the development and evaluation of control devices designed specifically for persons with physical disabilities. Many of these devices were designed to provide access to appliances in a home or work environment. While the dependency on other people for assistance has been greatly reduced, the viability of independent living has increased along with the demand for more sophisticated technical aids.

As the population of elderly Canadian continues to increase and as more adults with severe physical disabilities move out of institutions into group homes and private residences, there is a greater need for more specialized housing requirements. This goes beyond the construction or conversion of homes for easy access. Methods have to be developed which not only allow physically challenged people to move about more freely but also offers them greater access to their surrounding environment.

There are a number of stand-alone devices currently available which will control isolated aspects of the home environment. Installation and operation of many of these products, however, requires a level of technical knowledge and skill that often discourages the average homeowner. In addition, the degree of manual dexterity needed to access most of these systems makes them unsuitable for use by individuals with limited physical capabilities. The access method, in fact, presents the biggest challenge in designing a practical home control system. Yet the technology exists to build a human/machine interface that would be acceptable to most people with varying degrees of physical limitations.

Research into this area has indicated the feasibility of developing a home environmental control system, for persons with physical disabilities, that would be:

- flexible in the design, to meet the needs of various users.
- simple to install into existing homes.
- very easy to operate.
- relatively inexpensive.

Such a system would offer "hands free" management of home appliances, entertainment, security, and communications devices.

The prototype system, outlined in this report, was developed to evaluate the concept of using a small portable communications display terminal as a viable access method in a home environmental control system designed for physically challenged adults. Once assembled, the prototype was installed in the home of a quadriplegic person for testing. The test results, which reflected the user's response and the technical performance characteristics of the system, were evaluated and recommendations made for the further development of a marketable product.

2.0 OBJECTIVES

2.1.) Design and prototype an environmental home control system to meet the following criteria.:

- The system must be easy to operate with "hands free" access.
- Any resulting product should be easy to install with no custom wiring requirements.

- The design should incorporate features considered to be the most desirable by people with physical disabilities, providing these features are both technically and economically feasible.

- Any marketable product which may be developed must be affordable.

2.2.) Prototype a working model of the system using available technology.

2.3.) Install the system in the home of a quadriplegic person for evaluation

2.4.) Assess the evaluation information and if indicated pursue the development of a marketable product.

3.0 SYSTEM DESCRIPTION

3.1 SYSTEM DESIGN

The home environmental control system incorporates a number of design features which make it well suited for use by most physically challenged individuals.

- *Requires no special wiring needs.*
- *Modular construction facilitates custom configurations and future add ons.*
- *Voice operation makes possible "hands free" control.*
- *Portable communications terminal provides remote control, visual feedback, and telephone and intercom access capabilities.*
- *Control of AC appliances and lights, telephone, intercom, vcr and television.*

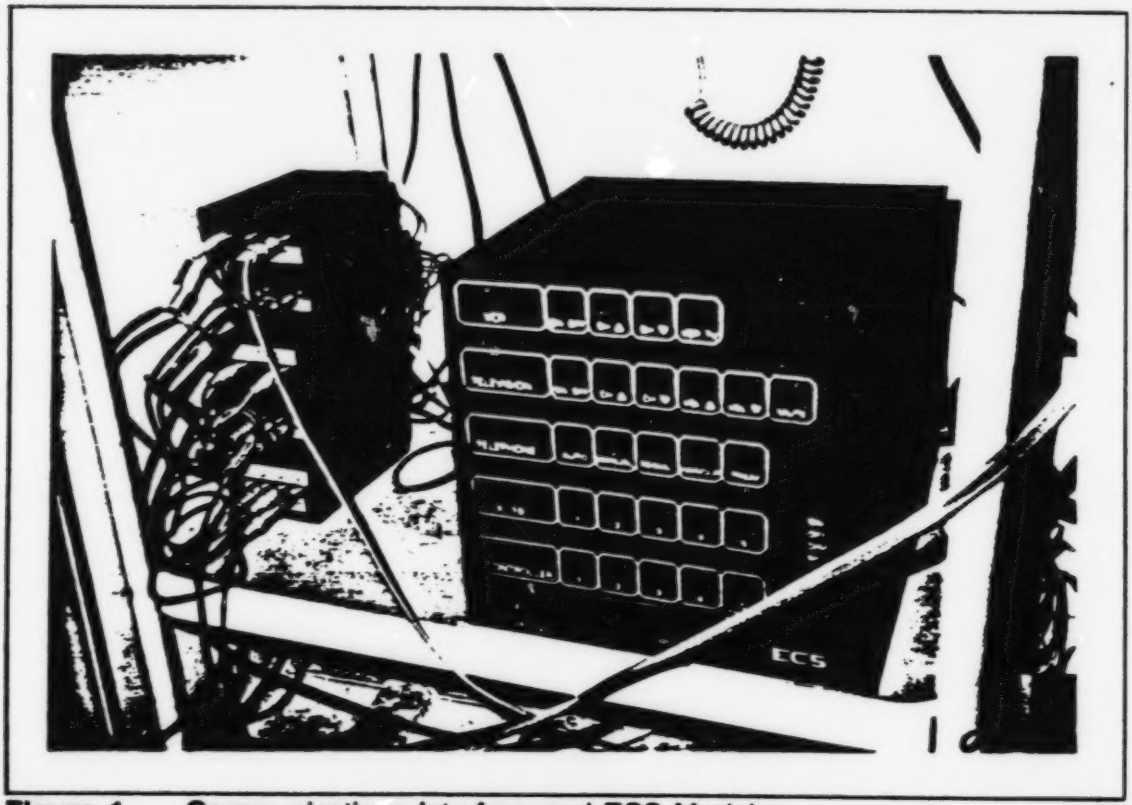


Figure 1 Communications Interface and ECS Modules.

The basic design consists of two main sections; the control section and the user interface. The control

section contains the voice recognition, microprocessor, communication, and control electronics which convert the incoming verbal commands to electrical control signals for the various devices in the surrounding environment.

The control section is accessed by way of a remote display terminal, which can be mounted to a wheelchair and provides the user with visual control information and two way audio for communications.

Figure 2 Wheelchair-mounted LCD Terminal and Communications Transmitter/Receiver.

3.2 PROTOTYPE

To readily evaluate the features of this design concept a prototype system was assembled from a number of individual components, each responsible for a particular function. This building blocks approach made any repairs, alterations or improvements much more easier to implement once the system was operational. The prototype components included:

Control Section:

Microprocessor - An IBM XT equipped with voice recognition hardware and specially designed software to activate the various control modules.

Control Electronics - Five modules to directly control the telephone, vcr, television, lighting, appliances, intercom and security camera.

Communications - A UHF band video and audio transmitter, a VHF band audio receiver,

a video switcher, an audio mixer, an audio distribution amplifier, an intercom audio interface, a telephone audio interface and a computer video adapter.

Remote Display Terminal:

Communications - A 4" LCD color screen to display computer software information and security camera image, a UHF band video receiver, and a VHF band audio transmitter all mounted under the right handrest of the wheelchair.

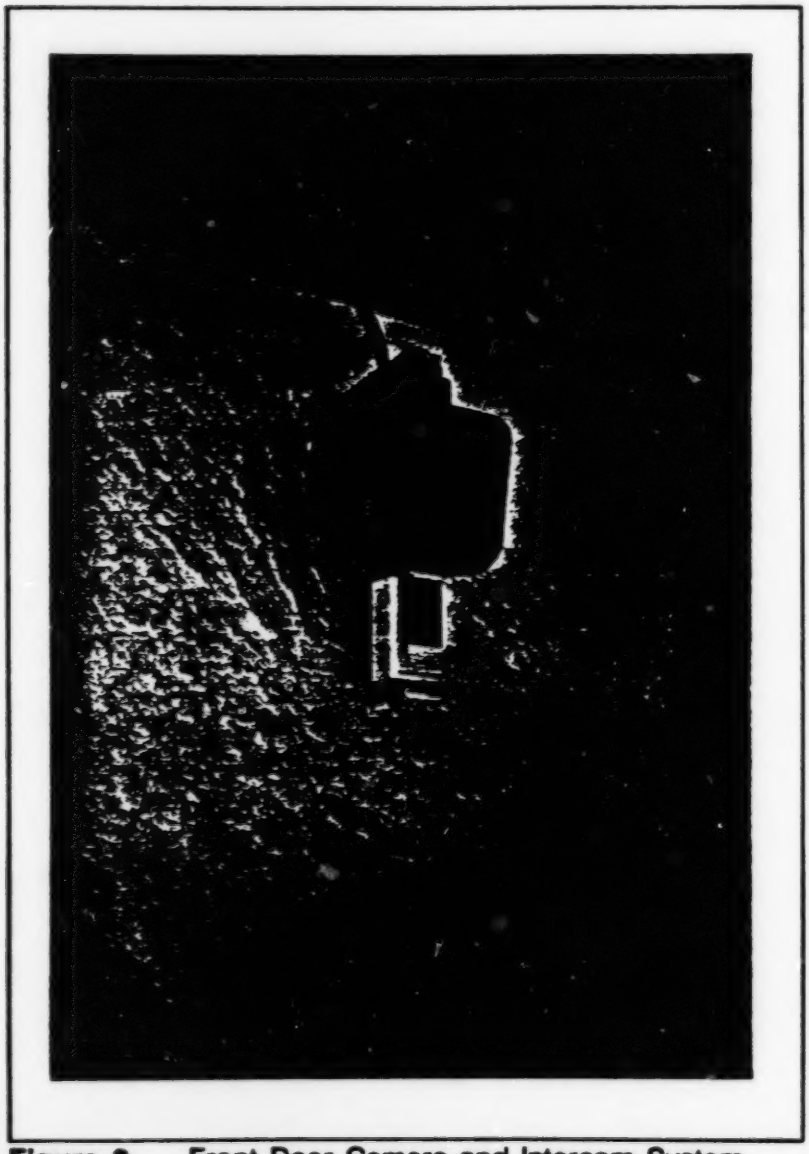


Figure 3 Front Door Camera and Intercom System.

3.3 CONTROL SOFTWARE

The software is organized to display a series of menus to lead the user through the available control choices. The first menu lists the five main control modules:

- *the main controller (for AC appliances and intercom control)*
- *the x10 module (for controlling AC devices through existing home wiring)*
- *the telephone dialler (plugs into standard phone jack and provides answer phone, autodial (for memory stored numbers), manual dial, redial, and hang-up functions)*
- *the television module (takes the place of the handheld infrared remote control that comes with most TV sets)*
- *the vcr module (operates the same as the television module)*

When one of these modules is selected, a second menu appears showing either the functions that can be executed or alternate control information. For example, if the user were to select C) TELEPHONE in the first menu below a second menu would appear, displaying the control options. Any further selection would result in a telephone operation (except for B) AUTODIAL). If AUTODIAL were chosen a third menu containing a list of up to twenty-five names and numbers (stored in memory) would appear. The user would simply speak the name and the number would be dialled.

First Menu:

```
        ENVIRONMENTAL CONTROL SYSTEM

A) MAIN CONTROLLER
B) X10 REMOTES
C) TELEPHONE
D) TELEVISION
E) VIDEO RECORDER
F) SET UP
```

Second Menu:

```
              TELEPHONE MODULE

A) ANSWER PHONE
B) AUTODIAL
C) MANUAL DIAL
D) REDIAL
E) HANGUP
```

3.3 CONTROL SOFTWARE cont...

Third Menu:

```
              AUTODIAL LIST

A) JOHN DOE                  987 6543
B) NAME
C) NAME
D) NAME
E) ETC.
```

The program works the same way for other selections. The menus leads the user down a logical path and list pertinent control information on the way. In this way the software provides accurate feedback for the user to insure reliable operation of the system.

The voice recognition software runs simultaneously with the control program. When a command word(s) is recognized by the voice program it tells the control program which selection has been made. The control program processes the selection information and sends out the appropriate control signal. Because the voice system is always running, waiting for a command, it will try to process all input including normal conversation. A person could accidently trigger unwanted control functions by simply talking to a friend. To deal with this problem, a method was incorporated into the software to stop the system from "listening". By simply saying the words "go to sleep" the software is put into an idle mode. In this mode the system will not respond to general conversation. Control commands will only be accepted again when the program is told to "wake up".

3.4 SYSTEM OPERATION

The portable communications display terminal is mounted to the test subject's wheelchair. It acts as a wireless gateway to the main control section. The user's voice is transmitted, via a radio link, to a computer equipped with a voice recognition circuit. The computer program matches the incoming voice command to previously stored commands in it's memory. When a voice command is recognized as a valid entry, the computer sends out the appropriate control signal to the stack of interface modules. These modules connect the computer to the various household devices. The user knows what devices and control options are available from the information displayed on the terminal's video screen. This visual data is sent from the computer to the terminal by way of a video transmitter. Two way communications between the terminal and the in-house telephone and intercom is also possible. For example, if the intercom is selected, the user's voice is routed to the intercom and both the voice and visual image of the caller is sent back to the terminals display. A telephone conversation works in a similar manner, minus the video portion.

4.0 TEST PROCEDURE

The prototype system was installed in the home of person with quadriplegia. He has no functional movement from the neck down and moves around with the aid of an electric wheelchair. He was chosen because of his past experience using a wide range of technical aids for the disabled. His home provided excellent conditions for the evaluation of a retrofittable system of this design.

The system was evaluated to determine the feasibility of the concept rather than a direct focus on the operation of each piece of equipment. A test procedure was established to document the user's subjective responses to his interaction with the system and to also acquire technical data regarding the viability of the overall design.

4.1 TEST SUBJECT'S FEEDBACK

The test subject was asked for comments and recommendations regarding the operation of the overall system. His feedback concerning the portable communications display terminal was based on responses to the following seven questions:

1.) Did the mounting position of the display terminal present any problems?

2.) Did you find the display terminal's menu program useful?

3.) Was the display's menu readable and easy to understand?

4.) Did the voice control feature work as you expected?

5.) Did the system respond to your voice commands reliably?

6.) Were tasks performed quickly enough? eg. answering the phone.

7.) Was the ability to use the terminal for telephone and intercom calls a useful feature?

Comment on any particular problems you had while operating the system.

General comments regarding design features or operating characteristics.

Recommend any improvements you feel should be made to the system.

4.2 TECHNICAL PERFORMANCE CHARACTERISTICS

Technical data that had any bearing on the performance characteristics were documented through an error logging program built into the software and through numerous site visits. The information was laid out as follows:

1.) Alterations or improvements made to the prototype system before and during the testing phase.

2.) Performance problems related to the design that could not be corrected.

3.) Limitations of the system's design.

5.0 TEST RESULTS

The test results are arranged into two sections: 1) the test subjects comments regarding the operation of the environmental control system and in particular the wheelchair mounted display (communications) terminal and 2) the technical results.

5.1 TEST SUBJECT'S FEEDBACK

1.) Although the prototype display terminal and associated electronics occupied substantially more space on the wheelchair than what the original design called for, the test subject indicated that the terminal was relatively inconspicuous and did not interfere with any of his daily routines, such as eating or wheelchair transferring.

2.) The display terminal's information was very useful for two major reasons. It provided verification that the right number had been dialled when using the telephone or when controlling other devices that could not be readily seen. It was also invaluable as a reference guide when a control device, function, or telephone listing was forgotten.

3.) The menus were very legible and easy to follow.

4.) The test subject had worked with a voice controlled device once before and found the voice recognition capabilities of this system much better than expected.

5.) The system was fairly tolerant of variations in voice quality due to colds etc., but occasionally commands had to be repeated. It was also difficult to remember all the various commands, which is why the visual feedback was so important.

6.) The reaction time of the system was good.

7.) The ability to have a private telephone conversation anywhere in the home was one of the highlights of using the system. For security reasons, it was very important to be able to access the intercom and a welcome bonus to be able to view a caller on the display screen.

Problems:

There were several areas in the house where the terminal's display would flicker slightly and the system would not respond to commands. On three occasions the voice system came out of "sleep mode" and started recognizing conversation which resulted in a program failure.

Light from the display screen was distracting while watching television in a dimly lit room. An on/off switch was installed during the test period and should be considered for any product. When viewing the security camera image from the front entry the menu information was switched off so the command sequence to return to the menu had to be memorized.

Recommendations:

The display terminal should have a quick release mechanism so that the terminal can be placed next to a bed during the night.

Additional support for a stereo system, burglar alarm and door opener should be considered.

5.2 TECHNICAL PERFORMANCE CHARACTERISTICS

5.2.1.) Alterations or Improvements Made Before and During Test Period:

The wheelchair mounted display terminal was modified for easier removal.

The audio speaker for telephone reception was mounted closer to the test subjects ear for more privacy.

An on/off switch was installed on the display terminal so that the light from the screen would not be distracting while viewing television in a dimly lit room.

The software was modified to reduce the time to switch from one menu to the next. Also a number of command words were made simpler at the request of the test subject.

The communications equipment was modified to put out a stronger signal when it was found that the test subject's electric wheelchair created interference in the video reception.

An automatic reset was incorporated into the software in the event of a program glitch or power failure.

5.2.2.) Uncorrectable Problems:

The most noticeable problem with the system seemed to be with the method used to send and receive audio/video information. There turned out to be a number of "dead spots" in the home where communication signals had trouble getting through.

The error logging program embedded into the software showed that on several occasions the main control program locked up and could only be reset by turning the power off and then on again.

5.2.3.) Limitations:

The communications display terminal could not be easily taken off the wheelchair and set beside the user's bed at night.

A total of 128 voice commands had to be trained by the test subject before using the system.

The names and telephone numbers listed in the program had to be manually entered with a keyboard.

Two systems close together could potentially interfere with each other's control functions.

6.0 SYSTEM EVALUATION AND RECOMMENDATIONS

The test subject's response was very enthusiastic regarding the overall performance of the prototype. He felt the concept of using a small portable communications display terminal (wheelchair mounted in this case) was a unique and practical approach. Other people with physical disabilities who have had an opportunity to see the system in operation have voiced similar views.

Most of the technical problems encountered during the test phase were minor. The software acted up on several occasions but with a little time the bugs can be removed and any improvements easily written into the program.

Technically, there are several design problems that have to be overcome before a reliable system can be realized. The most serious problem to be addressed is the method used to transmit and receive audio/visual data. The system currently uses RF technology similar to that of walkie talkies. Federal communications regulations limit the strength of RF transmissions so it is difficult to build equipment with enough power to send signals with 100% reliability. A viable alternative is to first digitize the audio, video, and computer data and then transmit them on a number of parallel channels simultaneously in a technique known as spread spectrum. This method would also allow coding of the signals so neighbouring systems would not interfere with each other. The Department of Communications has also set aside certain broadcast frequencies for users of spread spectrum devices.

A voice system that can be tailored to respond to personalized verbal commands has definite benefits. This type of voice recognition is known as "speaker dependent" and once the system has been trained it will only respond to that particular speaker. The time required to train the system to understand it's master's voice, however, could prove to be a weak point. Any set-up time should be kept to a minimum. Another possible approach would be to use a control program that provides numbered choices in the menu. This way a "speaker independent" system that required no training and could respond to any person's voice could be installed with a simple numeric vocabulary of 0 to 9 and maybe yes and no commands.

Regardless of what kind of programmable phone capability is incorporated into any home control system, the telephone numbers have to be entered manually. The prototype's control program had a setup mode which allowed the user to enter both numbers and names into the autodial phone menu. A final product will have to include an alphanumeric keyboard of some kind for this feature to be retained.

The prototype portable communications display terminal was made up from several components which made it somewhat bulky and power hungry. In the test situation it had to draw power from the wheelchair's battery. The final version would be highly integrated, making it much smaller and able to be powered by rechargeable batteries. The idea is, that at the end of the day, the device could be removed from the wheelchair with the flick of a switch and plugged into a bedside charger base unit much like pocket pagers with tabletop chargers.

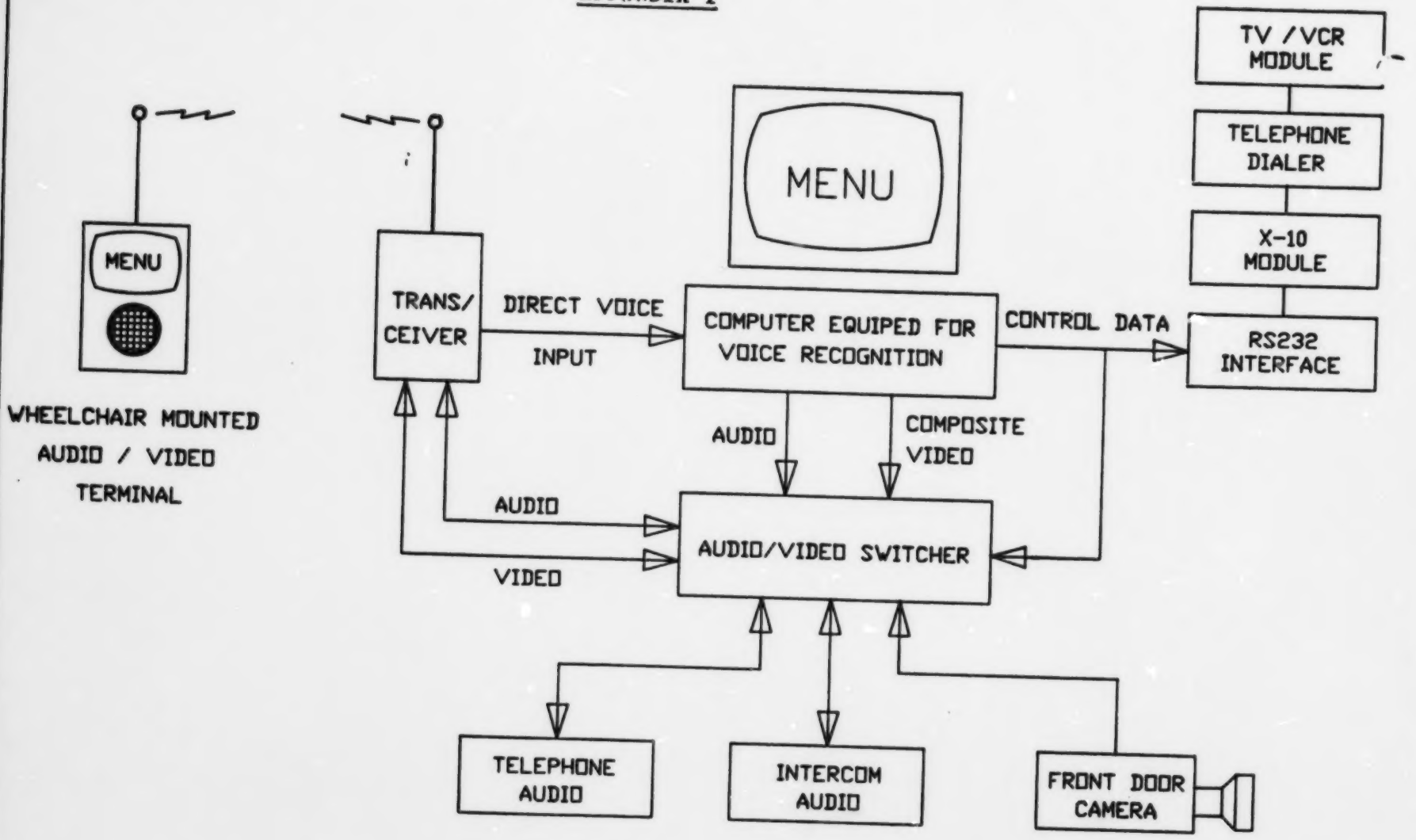
CONCLUSION

Since the project began, a number of alterations have been made to the initial design and several more improvements will have to be made before a viable product can be realized. Aside from these changes the basic design concept shows great potential.

The control section of the system will be the easiest to develop into a finished product. The individual subcomponents and various interface circuits will have to incorporated into a stand alone controller with a microprocessor core. Most of the circuitry was already designed for the prototype so it's primarily a case of repackaging. The only consideration that could require further research is the possibility of using a more sophisticated method of interfacing to household appliances. A local company is currently working on a device which would make appliances in the home a little smarter. Instead of sending a simple on/off control signal one way, the appliances would also send status information back to the controller. For example, if the telephone rings in the house, the television could be told directly to turn its volume down without a person's intervention. This company has expressed a great deal of interest in our design concept and a potential joint venture could result.

The communications display terminal will also require more attention. The test evaluation indicated that the method of wireless audio / video transmission was not suitable in the current configuration. As outlined in the evaluation and recommendations section, a technology known as spread spectrum holds more promise for reliable communications between the terminal and main controller. A telecommunications company familiar with this type of technology has offered to develop the communications part of our system for us and the details are presently being worked out.

APPENDIX 1



THE NEIL SQUIRE FOUNDATION

BLOCK DIAGRAM OF PROPOSED
HOME AUTOMATED SYSTEM